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ORIGINAL PAPER

Compatibility and complementarity of indigenous and scientific knowledge of wild plants in the highlands of southwest Saudi Arabia

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Abstract: This study presents a survey of wild plants commonly used by local inhabitants in the highlands of southwest Saudi Arabia. Based upon literature review, direct observation of local inhabitants, and questionnaire interviews, 36 plant species were assessed and given scores according to their use. The gaps between scientific and indigenous knowledge on the use of plants were estimated using a "compatibility ratio". The score values were estimated based on seven different use categories of ecosystem services, including food, forage, medicine, wood, beekeeping, research, and education. Additional structural categories include source of materials, shade, hedges, ornamental plantings, and soil stabilization. There are discrepancies between indigenous knowledge (IK) and scientific knowledge (SK) but in most cases, SK of the species supports the IK and plant users preference. The results also provide information that challenges assumptions about the consistency of IK with SK. Our study highlights the importance of understanding the cultural context and uses of wild plants. Biodiversity-based knowledge holds promise for contributing to sustainable use of wild plant resources and related traditions. The success of such endeavours depends on the compatibility and complementarity of indigenous and scientific knowledge.

Keywords: multipurpose use plants, importance value, compatibility ratio, Sarawat mountains, arid lands

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Introduction

Different people value wild plants as biological resources in different ways (*sensu* MEA 2005; Anonymous 2010). Local people value plants as the source of goods and services; individuals see plants as source of return on capital investments in terms of grazing, timber, or part of their leisure and enjoyment; economists place monetary values from direct plant use as a source of some human needs; scientists value it for their research and teaching material; anthropologists see it as language of symbols and part of heritage; artists see plants as subject to paint pictures or photograph; and religious valuation refers to secular veneration of nature and to historical perspectives (UNEP 1995; OECD 2002; Cork et al. 2002; Krishnamurthy 2003).

Plant resources have both use and non-use values (UNEP 1995). The use value includes both direct direct use of the resource and indirect functional uses. Direct-use values are derived from interaction with the plant resource, while the indirect use is derived values from the direct use. The non-use or passive use value is assigned as existence value of the species, usually towards non-human users. According to the number of uses, plants may be grouped into single use or multipurpose use plants. Multipurpose use plants are important for their economic, environmental, industrial, historical, aesthetic, and spiritual role to sustain the life of indigenous people in different ecosystems. Despite the modernization of contemporary societies, indigenous people still rely on wild plants in many ways and appreciate the benefits gained from wild plants as part of nature's precious gifts.

Multipurpose use plants (MPUP) are defined here as the wild plants considered by people for preferably more than one in-

tended use. Regardless of the number of actual or potential uses, MPUP contribute to the functional and ecological stability of ecosystems (Von Carlwolitz 1984). Overconsumption of multi-purpose use plants imposes considerable pressure on the mountain wild plants in the deserts and semideserts of the Middle East. In these ecosystems, the rate of exploitation, particularly through commercialization of these resources, is more than the rate of establishment and recruitment of new individuals (Hegazy 1990). Less attention has been paid to the socio-economic valuation and conservation of MPUP resources (UNEP 1995).

Advances in quantitative ethnobotany have witnessed significant progress over the past few decades (Pardo-de-Santayana et al. 2010). Previous studies measured the value of plant species through constructed indices combining cultural, practical, and economic dimensions (Reyes-Garcia et al. 2006). The cultural dimension was estimated as function of the potential uses and number of people reporting plant use, while the practical dimension considered the number of observed uses, number of times the species was used, and the potential lifetime of the species. The economic dimension was estimated as a function of the number of times the plant was used and the market price of the species.

Traditional or indigenous knowledge (IK) is a local body of knowledge practice and belief, evolving from adaptive processes that is unique to a given culture or society. IK is handed down through generations as traditional practice and cultural transmission. IK can be used as a base for local plant resource use and sustainable development. Scientific knowledge (SK) is a product of objective testing of an observation and formulated hypotheses with data collected from scientifically designed experiments, based on the principles of repeatability and predictability. Until recently, IK was often hidden and dismissed as scientists considered it as anecdotal and unscientific.

Hitherto, scientists have recognized the importance of IK building on science-based communication with diverse local communities as a tool in scientific research to add depth and meaning to the basic SK concepts. Over the past few decades, a growing accumulation of literature has emphasized the importance of incorporating IK practices into SK for development and conservation of natural resources (Sillitoe 1998; Dekens 2007; Mercer et al. 2009; Darwish and Aburjai 2010). However, in aridlands of the Middle East, the practical applications of IK occur on small scale, that require both science and local knowledge stakeholders to collaborate in systematically knowledge-based strategies for sustainable development (Rai et al. 2000; Cork et al. 2002; Cordell and Colvard 2005; Alzweiri et al. 2011, Siew and Doll 2012).

Given the dichotomy of arguments on IK and SK, it makes more sense to discuss multiple dimensions of different knowledge and logics. Arguments on the compatibility and complementarity of IK and SK need to move beyond the dichotomy of indigenous versus scientific and work towards building cross-cutting themes to bridge the divide. This requires integration between IK and SK based on a mutual understanding of the cultural and epistemological basis of each (Agrawal 1995 and 1996; Mercer et al. 2009). It is essential to create a participatory approach not to disempower the IK, but to integrate and bridge the divide.

Given the lack of ethnobotanical studies in mountain ecosystems of the Middle East, this study aims to describe the domain of wild plant resource use, identify which plant species are used for which purpose, assess the indigenous importance of different plant use categories, and explore the compatibility and discrepancy of indigenous and scientific plant knowledge in the Asir highlands, southwest Saudi Arabia.

Material and methods

Study population

The study population was chosen from local people who live in the Shada Mountains of southwest Saudi Arabia. The total population living in the study area (Shada Mountains) is about 600 people. Most of the families have their permanent residence in the mountains, while few of them have another residence in the nearby towns, Belqurashy and Makhwa, where they spend the work week. A total sample of 100 participants were identified for the study. The population sample consisted of 54 men and 46 women, and the average age of the participants was 52.6 years (range 30–85 years). At this age, the participants are expected to be more aware of plant resources than the young. The field researchers were divided into men and women interviewers as it was not possible for men to interview women participants and vice versa.

Methods of data collection

Participatory rural appraisal techniques (Briggs et al. 1993, 1999) supported by questionnaire and direct interviews were used for gathering information from individuals or groups of local inhabitants. This technique depends on the participation and contribution of local people who were asked to rank a list of regularly used plants and then show the researchers these wild plants in the field. Then specimens of these plants were collected and identified. Discussions and interviews were oriented according to previously identified set of points and questions on different uses of plant resources, methods of conservation, and traditional control that exists over plant utilization. In some cases, the questions were asked indirectly through conversations and formed the basis of discussions. This technique helped to build up trust between local people and researchers, and proved to be appropriate in a conservative society such as Saudi Arabia.

Assessment of the importance value

The value of plant species found to be of importance for local people was estimated. A three-pronged approach was used to assess the importance value of the study species (Belal and Springuel 1996) as based on literature survey, direct observations of local people, and interviews or informal discussions. Seven common indigenous uses of mountain plants were identified for

the assessment: food, forage, medicine, wood, bee keeping, research, and education, as well as other functional uses, such as source of materials, shade, hedges, soil stabilization and ornamental. The seven uses were identified as based on informal conversations with local people and literature survey.

The importance value (IV) was estimated for each plant species based on the seven use categories (Table 1). For each species, a score of 4 suggests minimum seasonal use, while a score of 8 suggests maximum year-round local use. A score zero for a particular use indicates no economic value for the species to local people. The sum of IVs for all uses per species—expressed as relative percentage of the maximum relative score—represents its total importance value (TIV). Plants with multiple uses fall into more than one category. The percentage total importance value was calculated as:

$$TIV\,\% = (U_1 + U_2 + U_3 + U_4 + U_5 + U_6 + U_7) / 56 \times 100 \qquad (1)$$

where U is IV for each particular use; U_1 the food use, U_2 the forage use, U_3 the medicinal use, U_4 the wood use, U_5 the bee keeping use, U_6 the research and education use, and U_7 is the other uses. The other use category includes specific structural or functional use, e.g., shade, hedge, windbreak, ornamental, and household uses. A maximum value 8 for all seven uses gives an overall maximum value of 56, which would produce a TIV of 100% for all plant species.

Table 1: Estimating importance values for use of plant species in southwest mountains region of Saudi Arabia.

Criteria	Category	Score
Availability around the year	Seasonal	1
	All the year	2
Species abundance	Rare	1
	Abundant	2
Species user	Only mentioned in literature	1
	Mentioned by local people	2
Use intensity	Low	1
	High	2

Indigenous knowledge

The indigenous knowledge index for each species was calculated on the cultural value of species (Reyes-Garcia et al. 2006):

$$CV = Uc \times Ic \times \sum IUc \qquad (2)$$

where CV is the cultural value of a particular species. Uc is the total number of uses reported for the species divided by the seven potential uses considered in this study, i.e., food, forage, medicine, wood, bee keeping, research, educationand functional uses. Ic is the number of informants who recorded the species as useful divided by the total number of people participating in the survey. IUc expresses the number of informants who mentioned each of the seven uses of the species divided by the total number of participants. The value is expressed as the indigenous knowledge index with values ranges from zero to one.

In this study, it was not possible to estimate the practical and economic values of plant use due to difficulty of capturing the market price of each use. The actual use of each species was calculated as total importance value (TIV)

Scientific knowledge

Due to lack of information, it was not possible to evaluate the scientific knowledge in different use categories of the species. In this study, an attempt was made to estimate only the medicinal scientific knowledge as based on the active chemical constituents and pharmacological characteristics of a particular species. For example, if 50 chemical compounds are known for a species and only 20 of those compounds have medicinal applications and pharmacological effects, the medicinal scientific knowledge index is calculated as ratio of 20/50 which gives value 0.4. The index value ranges from zero to one.

Compatibility ratio

To assess the scientific validation of the traditional use against the scientific knowledge of the species, the indigenous-scientific knowledge ratio is calculated. The compatibility ratio is obtained by dividing the indigenous knowledge index by the scientific knowledge index. When all indigenous uses of the species are scientifically proved where the known scientific applications matches all indigenous applications of the species the compatibility ratio is equal to one. Ratios higher than unity means that there are still gaps in the scientific knowledge of the species and all indigenous uses of the species need scientific validation. When the ratio is lower than unity, this means that scientific knowledge of the species use exceeds the indigenous knowledge. These species can potentially be used to benefit the local people more than their current indigenous use.

Plant life-form, abundance and exploitation

The life-forms of the study species is identified as trees, shrubs, lianas, and herbs. The local commonness and rarity of species at their range of distribution in the country were considered according to Collenette (1999), local information, and our field observations. The rate of plant resource exploitation was estimated according to the percentage of the local population using the plant resource. Five categories for the rate of exploitation were adopted as follows: very high =more than 75%; high =50%–75%; moderate =25%–50%; low =5%–25%; and occasional =less than 5% of individuals who participated in the questionnaire mentioned the plant use.

Results

Plant use

Scores representing the plant use of the identified seven use categories are shown in Table 2. Different species were observed

to have up to 7 common uses such as food, forage, medicine, wood, beekeeping, research and education. Other uses include ornamental, house constructions, soil stabilization, hedgerows, windbreaks, and household uses. Three species *Acacia* sp., *M. peregrina*, and *O. europaea* are known to local mountain dwellers as top multipurpose species. In the second rank, comes species having 6 uses including *B. salicina*, *C. quadricincta*, and *M. laurifolia*, while others such as *C. myrrah*, *G. villosa*, *O. fruiticosa* and *R. lycioides* have 5 uses. The remaining study species have recorded some 2 to 4 uses.

Table 2: Importance value of the study species in seven different plant uses. The other functional uses include hedgerows, windbreaks, ornamental and household uses.TIV= total importance value.

Species	Food	Forage	Medicine	Wood	Bee keeping	Research/ education	Functional uses	TIV (%)
Acacia tortilis (Forssk.) Hayne	4	8	6	8	7	5	8	82
Adenium obesum (Forssk.) Roem. & Schult.	-	-	7	-	-	4	4	26
Anisotes trisulcus (Forssk.) Vahl	-	-	7	-	-	4	6	30
Breonadia salicina (Vahl) N. Hepper & J.R.I. Wood	-	4	4	6	4	4	5	48
Cadaba farinosa Forssk.	-	-	6	-	-	-	4	17
Capparis tomentosa Lam.	-	-	6	-	-	4	-	17
Centaurothamnus maximus Wagenitz & Dittr.	-	-	-	-	-	4	6	17
Cichorium bottae Defl.	4	4	-	-	-	-	-	14
Cissus rotundifolius (Forssk.) Vahl	4	-	-	-	-	4	-	14
Coccinea grandis (L.) Voigt	7	-	4	-	-	4	-	26
Commiphora quadricincta Schweinf.	4	6	8	4	-	5	5	57
Commiphora myrrah (Nees) Engl.	-	6	8	4	-	5	5	50
Crataegus sinaica Boiss.	-	-	-	-	4	4	4	21
Desmidorchis retrospeciens (Forssk.) Plowes	-	-	6	-	-	4	4	25
Dobera glabra (Forssk.) Poir.	-	-	-	-	-	4	6	17
Dracaena ombet Kotschy & Peyr.	-	-	6	-	-	-	4	17
Duvalia velutina Lavr.	-	-	4	-	-	-	5	16
Ephedra foeminea Forssk.	5	6	6	-	-	4	4	44
Euphorbia ammak Schweinf.	-	4	8	-	-	4	6	39
Ficus palmata Forssk.	6	4	6	-	-	4	4	42
Grewia villosa Willd.	6	-	4	4	4	-	4	39
Hyphaene thebaica (L.) Mart.	8	-	7	4	-	4	8	55
Jasminum grandiflorum L.	-	-	5	-	5	-	4	25
Juniperus phoenicea L.	-	-	7	8	-	8	8	55
Juniperus procera Hochst. ex Endl.	4	-	8	8	-	8	8	64
Mimusops laurifolia (Forssk.) Friis.	4	-	4	4	4	4	4	42
Moringa peregrina (Forssk.) Fiori	8	7	8	6	4	4	5	75
Olea europaea L. subsp. *africana* (Mill) P.S. Green	8	8	7	4	8	4	4	76
Otostegia fruiticosa (Forssk.) Penz. subsp. *schimperi* (Benth.) Sebald	-	4	4	-	8	4	4	50
Pistacia falcata Becc. ex Martelli	-	-	6	-	-	4	5	26
Rhamnus disperma Ehrenb. ex Boiss.	-	4	6	-	4	-	4	32
Rhamnus lycioides L. subsp. *oleoides* (L.) Jahand. & Maire	4	4	6	-	4	-	4	39
Rosa abyssinica Lindley	-	-	6	-	6	4	4	35
Ruta chalepensis L.	-	-	6	-	-	4	-	17
Senecio asirensis Boulos & J.R.I. Wood	-	-	4	-	-	-	4	14
Trema orientalis (L.) Blume	-	4	4	-	-	-	4	21

Food plants.

Many wild food plants are still important for local residents of the mountain ecosystems in Saudi Arabia. The wild food sources are used for leisure or to complement the traditional food as additional nutrients. The edible plant parts include leaves, fruits, and seeds are collected and used fresh, dry or cooked (Table 2). Fruits of *C. grandis* and *J. procera* are edible either fresh when mature or cocked when premature and green in colour. The mature fruits of *E. foeminea* and *F. palmata* are eaten fresh, while seeds of *A. tortilis* and *A. gerrardii* eaten when premature and succulent and flowers eaten as sweet. The white fresh gum of *A. ge*rrardii is eaten fresh and considered good source of energy. The premature succulent fresh seeds of *M. peregrina* are edible, while its nutritive ban oil is extracted from mature dry seeds. The

fruits of *O. europaea* are edible as pickles or cooked, and used for oil extraction. The dry fruits of *H. thebaica* are edible and used in vinegar production. The fruit pulp of *M. laurifolia* is edible fresh or cooked, while leaves are used dry as food additive.

Forage

Species are considered pasture plants when grazed or supplied as fodder to domestic animals particularly camels, sheep, and goats. Different animals are selective in their grazing, either for the plant species or its parts. Acacias and Commiphoras are the most grazed species by all domestic animals, while *E. foeminea* is preferred mostly by camels (Table 2). The remains of the pressed *M. peregrina* seeds and *O. europaea* fruits are used as supplemental nutritive fodder. Leaves of *B. salicina* and *F. palmata* are used as fodder at time of shortage.

Medicine

Most of the study plant species were found to contain medically active constituents and are still used by local residents for many kinds of medicinal purposes. Some of these species are common in the region, while others became very rare because of over collection (Table 2). Plants are used in the form of extracts from different fresh or dry parts, latex, gums, and liquid exudates. The direct use of plant material for medicinal purposes is shown in *A. tortilis* and *C. myrrah* (stem exudates); *F. palmata* (latex); *O. europaea* and *J. procera* (chewing of fresh leaves); and *M. peregrina*, *C.* myrrah, *B. salicina* and *O. europaea* (preparations and extracts). Some species including *C. quadricincta, C. myrrah, E. ammak, J. procera* and *M. peregrina* have scored the highest medicinal importance value of 8 among the study species. Alternatively, few species, e.g., *C. maximus, C. bottae, C. rotundifolius, C. sinaica* and *D. glabra* have no medicinal use for local residents. The species *D. velutina, O. fruiticosa* and *P. falcata* are known to local people as medicinal plants used in folk medicine, but there is no previous literature on their chemical constituents, pharmacology, and toxicology. The medicinal importance value of these three species ranges from score 4 to 6.

Wood

All trees and shrubs are liable to be used as source of wood and timber (Table 2). However, because of modernization, wood consumption is mainly for leisure. The use of wood for fire or charcoal making occurs occasionally. Acacia wood is the most frequently used as it produces higher heat and slower burning compared to the other woody plants in the region. Timber from Junipers, *H. thebaica,* and Acacias is used as building material and in other rural-use purposes.

Bee keeping

Bee keeping is important activity for mountain residents not only for their own consumption but also for income generation. Among the mountain flora in the region, local people have named several species to be of considerable apiculture value (Table 2). The most important species are Acacias, *O. fruiticosa*, *O. europaea*, and *M. laurifolia*. Of less importance, the wood of *H. thebaica* and *B. salicina* is used for making hives. The seasonal field crops in the mountain farms—e.g., sorghum, vegetables, coffee plants, forage crops, and fruit trees—are very useful in terms of nectar generation of prime importance for bee keeping industry.

Mountainous landscape creates several plant phenological niches due to various altitudes, exposure, and slope, which enable various plant species to produce high-quality blossoms on a large scale. Concerning the regularity of the flowering seasons and constancy of blossoms, season length varies according to the habitat characteristics from year to year. The over 500 plant species in the region constitute different phenological groups, each group reaches full blossom in different season.

Research and education

It is possible to bring global knowledge to local indigenous people, but very difficult to learn about or export knowledge from local people unless it has been scientifically proven. Meanwhile, IK is usually embedded in cultural values as part of everyday life of the local community. Therefore, research and education are needed to validate such knowledge before dissemination beyond the local boundaries.

Concerning the mountain plants in the study area, many still need to be validated for their indigenous use and educational importance. For example, *C. bottae* is locally known as a substitute for tea and coffee, as well as a grazing plant for sheep and goats. Hitherto, no scientific proof or study on this species has been done to test or validate its local uses. The same is true for many other species (Table 2). Alternatively, the nutritional, medicinal, and forage potentialities of many species were scientifically proven through its chemical composition and constituents of active compounds. For many other species, there still are gaps in scientific information, including *C. rotundifolius*, *S. asirensis* and *T. orientalis*.

Functional uses

The other uses of plants are for specific functional and structural characteristics beside their major uses (Table 2). Trees and shrubs are used for shade, hedges, and windbreaks. Some of the species are used as climbers on wire fences, e.g., *C. grandis* and *C. rotundifolius*, while others used for ornamental purposes, e.g., J. *grandiflorum, D. retrospeciens, R. abyssinica, S. asirensis* and *C. maximus*. The *G. villosa* and Acacias are used for charcoal production, while *C. quadricincta* is a source of incense. The identified and observed uses for the study species include many traditional local industries and tools, wind breaks, hedgerows, ornamental, cosmetics, phytoprotective applications, and source of phytochemically important materials, such as tannins.

Total importance value

Economically important wild plant species are valued based on their scientific, cultural, and economic uses. The total importance value (TIV) of the study species ranges from 14% in *C. bottae*, *C. rotundifolius* and *S. asirensis* to 82% in Acacias (Table 2). All species with one or two use categories—such as *C. tomentosa*, *C.*

maximus, *D. ombet*, *D. velutina*, *R. chalepensis* and *S. asirensis*—usually have the least TIV. Most of the species having three or four use categories have TIV ranged from 21% to 50%, such as *T. orientalis*, *P. falcate*, *J. grandiflorum*, *E. ammak*, *A. trisulcus* and *A. obesum*. As for species having five to seven use categories are characterized by TIV more than 50%, these include *C. quadricincta*, *H. thebaica,* and *J. procera*. These plants are known to be multipurpose use species. Exceptions may occur when the species attains relatively low scores under the different use categories, e.g., *B. salicina, E. foeminea*, *F. palmata*, and *M. laurifolia*. In general, multipurpose use species have relatively higher TIV than single- or few-use species.

Knowledge indices

The indigenous knowledge index (IKI) of the study ethnospecies ranged from score 0.003 to 0.935 (Table 3). The species having IKI less than score 0.10 are known to have 2 or 3 uses of the seven identified plant uses. The species *Acacia* sp., *J. procera, M. peregrina* and *O. europaea* have IKI more than score 0.50 and known as multipurpose species. The remaining species have IKI ranges between score 0.10 to less than 0.50 including *B. salicina, Commiphora sp., E. foeminea* and *H. thebaica*. The scientific knowledge index (SKI) ranged from score 0.20 to 0.60. The multipurpose use species attained the highest SKI values. All remaining study species reached lower SKI than score 0.60.

The compatibility and complementarity of IK and SK as evaluated by the IK:Sk ratio demonstrates values ranged from almost negligible or very low ratio (0.013) in *C. farinosa*, *C. tomentosa,* and *R. chalepensis* to ratio 1.588 in Acacias (Table 3). Species that attained ratio values more than unity indicate their traditional local multipurpose use outweigh the scientifically proven medicinal usage of the species, e.g., Acacias, *H. thebaica*, *M. peregrina* and *O. europaea*. This means that these species need more scientific research to prove the validity of their indigenous use. The ratio value around unity—as in the case of *M. peregrina*, *J. procer*a, *C. myrrah* and *B. salicina*—indicates the compatibility of the indigenous use and the scientifically proven use of the species. Alternatively, species attained ratio values less than unity indicate that they have the potential for better and more potential use than their current traditional uses, e.g., *C. grandis*, *E. foeminea*, *E. ammak*, *Rhamnus* sp., *R. abyssinica,* and *T. orientalis.*

Plant life-form, abundance and exploitation

Trees and shrubs constituted the majority of the study species where most of them are locally common with various rates of exploitation ranged from occasional to very high (Table 4). The succulent trees and shrubs are locally common, but their use by local people is low. The two herbs *Ruta chalepensis* and *Senecio asirensis* are locally common with moderate and low rate of exploitation respectively. The herb *Cichorium bottae* is locally endangered with moderate rate of exploitation. The succulent and liana species are locally common with low rates of exploitation. The endemic rare shrub *Centaurothamnus maximus* is occasionally used by the local people.

Table 3: Indigenous medicinal knowledge index (IKI), scientific knowledge index (SKI) and compatibility ratio (IKI/ SKI ratio) of the study species.

Species	IKI	SKI	IKI/ SKI ratio
Acacia tortilis (Forssk.) Hayne	0.953	0.60	1.588
Adenium obesum (Forssk.) Roem. & Schult.	0.026	0.30	0.087
Anisotes trisulcus (Forssk.) Vahl	0.076	0.48	0.158
Breonadia salicina (Vahl) N. Hepper & J.R.I. Wood	0.355	0.34	1.044
Cadaba farinosa Forssk.	0.004	0.31	0.013
Capparis tomentosa Lam.	0.003	0.20	0.015
Centaurothamnus maximus Wagenitz & Dittr.	0.004	0.20	0.020
Cichorium bottae Defl.	0.013	0.20	0.065
Cissus rotundifolius (Forssk.) Vahl	0.028	0.36	0.078
Coccinea grandis (L.) Voigt	0.052	0.30	0.173
Commiphora quadricincta Schweinf.	0.482	0.40	1.205
Commiphora myrrah (Nees) Engl.	0.419	0.40	1.048
Crataegus sinaica Boiss.	0.010	0.32	0.031
Desmidorchis retrospeciens (Forssk.) Plowes	0.025	0.44	0.057
Dobera glabra (Forssk.) Poir.	0.010	0.30	0.033
Dracaena ombet Kotschy & Peyr.	0.012	0.36	0.033
Duvalia velutina Lavr.	0.010	0.30	0.033
Ephedra foeminea Forssk.	0.349	0.44	0.793
Euphorbia ammak Schweinf.	0.116	0.44	0.262
Ficus palmata Forssk.	0.113	0.36	0.314
Grewia villosa Willd.	0.114	0.42	0.271
Hyphaene thebaica (L.) Mart.	0.477	0.36	1.325
Jasminum grandiflorum L.	0.026	0.50	0.052
Juniperus phoenicea L.	0.465	0.56	0.830
Juniperus procera Hochst. ex Endl.	0.565	0.56	1.009
Mimusops laurifolia (Forssk.) Friis.	0.346	0.48	0.721
Moringa peregrina (Forssk.) Fiori	0.619	0.60	1.032
Olea europaea L. subsp. *africana* (Mill) P.S. Green	0.810	0.60	1.350
Otostegia fruiticosa (Forssk.) Penz. subsp. *schimperi* (Benth.) Sebald	0.248	0.32	0.775
Pistacia falcata Becc. ex Martelli	0.054	0.50	0.108
Rhamnus disperma Ehrenb. ex Boiss.	0.101	0.40	0.253
Rhamnus lycioides L. subsp. *oleoides* (L.) Jahand. & Maire	0.158	0.40	0.395
Rosa abyssinica Lindley	0.134	0.43	0.312
Ruta chalepensis L.	0.012	0.32	0.038
Senecio asirensis Boulos & J.R.I. Wood	0.010	0.20	0.050
Trema orientalis (L.) Blume	0.062	0.26	0.238

Discussion

Local residents in the mountains of southwest Saudi Arabia have a wealth of information on plant uses in their respective region. They can provide leads for scientific validation of their indigenous knowledge. They view plant diversity in their region as valuable cultural heritage and play an important role in revitalizing cultural identity and tradition. Because of the modernization movement in the country, most plant indigenous knowledge remains only in the memory of elderly people who realize the

importance of plant diversity as valuable component of their culture and environment. Despite the direct reliance of the people on wild plants as source of income is diminishing gradually, there is still awareness and appreciation of their value as a renewable resource that must be conserved and sustainably used.

Table 4: Life-form, abundance and exploitation rate of the study species.

Species	Life-form	Abundance	Rate of exploitation
Acacia tortilis (Forssk.) Hayne	Tree	C	High
Adenium obesum (Forssk.) Roem. & Schult.	Shrub	C	O
Anisotes trisulcus (Forssk.) Vahl	Shrub	C	Low
Breonadia salicina (Vahl) N. Hepper & J.R.I. Wood	Tree	R	M
Cadaba farinosa Forssk.	Shrub	C	O
Capparis tomentosa Lam.	Shrub	R	O
Centaurothamnus maximus Wagenitz & Dittr.	Shrub	R/En	O
Cichorium bottae Defl.	Herb	En	M
Cissus rotundifolius (Forssk.) Vahl	Liana	C	Low
Coccinea grandis (L.) Voigt	Liana	C	Low
Commiphora quadricincta Schweinf.	Tree	C	M
Commiphora myrrah (Nees) Engl.	Tree	C	High
Crataegus sinaica Boiss.	Tree	R	M
Desmidorchis retrospeciens (Forssk.) Plowes	S/Shrub	C	Low
Dobera glabra (Forssk.) Poir.	Tree	C	M
Dracaena ombet Kotschy & Peyr.	Tree	C	M
Duvalia velutina Lavr.	S/Shrub	C	Low
Ephedra foeminea Forssk.	Shrub	C	Low
Euphorbia ammak Schweinf.	S/Tree	C	Low
Ficus palmata Forssk.	Tree	C	M
Grewia villosa Willd.	Shrub	C	Low
Hyphaene thebaica (L.) Mart.	Tree	C	M
Jasminum grandiflorum L.	Shrub	C	M
Juniperus phoenicea L.	Tree	C	High
Juniperus procera Hochst. ex Endl.	Tree	C	High
Mimusops laurifolia (Forssk.) Friis.	Tree	R	High
Moringa peregrina (Forssk.) Fiori	Tree	R	High
Olea europaea L. subsp. *africana* (Mill) P.S. Green	Tree	C	M
Otostegia fruiticosa (Forssk.) Penz. subsp. *schimperi* (Benth.) Sebald	Shrub	C	High
Pistacia falcata Becc. ex Martelli	Tree	C	Low
Rhamnus disperma Ehrenb. ex Boiss.	Shrub	C	Low
Rhamnus lycioides L. subsp. *oleoides* (L.) Jahand. & Maire	Shrub	R	High
Rosa abyssinica Lindley	Shrub	C	Low
Ruta chalepensis L.	Herb	C	M
Senecio asirensis Boulos & J.R.I. Wood	Herb	C	Low
Trema orientalis (L.) Blume	Tree	R	Low

Note: S--Succulent; C--common, R--Rare, En--Endemic, En--Endangered O--Occasional, M--Moderate

Multipurpose use plants are the most heavily used for medicinal purposes, research and education, and other specific structure use categories. The other use categories including food, forage, wood and bee keeping come to the second category and all of almost parallel weight of plant use. Interesting to recognize that traditional use of plants in the mountain region of the country goes side by side with the counterpart modern items, for example, pharmaceutical medicine with herbal medicine, hedges with concrete walls, shade trees with patios, and fire screens with gas or electrified kitchens. This confirms the need for conservation and sustainable use of biodiversity in the arid land ecosystems (Belal and Springuel 1996; Alzweiri et al. 2011).

Compatibility and complementarity of knowledge are now necessary for capturing indigenous knowledge from local communities to be better conserved and developed based on scientific knowledge. The custodians of indigenous knowledge are motivated to divulge their ideas in the larger interest of humanity by protecting their intellectual property rights. Linkages between universities and grassroots innovators, synergy between local communities, research institutes, and other industries is essential for developing indigenous knowledge in conjugation with modern sciences. The compatibility and complementarity of IK and SK of mountain plants still requires validation, which include its significance, relevance, reliability, functionality, effectiveness, and transferability (Sen 2005).The success of an indigenous process does not necessarily ascertain its efficacy in other locations. This is usually confronted with cultural, political and economics of the recipient community. An important issue is that IK has to go beyond conveying the information. This can be achieved by scientific testing of knowledge value and use in different categories of plant uses. The social and environmental feasibility are deemed necessary to be scientifically proved and examined.

Contrasting IK with SK demonstrates both compatibility and discrepancy. Stressing the complementarity and consistency between IK and SK will decrease the gap between science and culture, support plant-resource conservation and development, and maximize the ecosystem goods and services (Sen 2005; Reyes-Garcia *et al*. 2006; Siew and Doll 2012). Our results show that compatibility and discrepancy of IK and SK may outweigh each other depending on the level of knowledge gaps. This means that, if thoroughly investigated, the species may provide more goods and services for local use than the current indigenous use. The fundamental challenge in development of botanical resources for local people today is to strengthen the harmonization and dismantle the discrepancy between IK and SK. This will support decision-making for socio-economic development and poverty alleviation in different local communities.

Based on the complementarity of IK and SK, at the present time, there are some constraints to sustainable development of EIWPS. The most important are the lack of economically and ecologically feasible knowledge, and the absence of investment priorities adapted to wild plant use. Financial support is limited in this field because chances for success usually based on long-term plans. Although this field of investment may not be economic in the short term, we have to look forward to the needs of our successors and have the responsibility for securing the future of the socioeconomic value of EIWPS. However, some possible opportunities for the future use of EIWPS may exist through oriented-research toward development of EIWPS as well as the increased public awareness not only among local people but also at a nationwide scale.

At the present time, under the increased rate of plant cultural biodiversity loss, it is not enough to document the indigenous

plant knowledge held and nurtured by the local communities. There is a pressing need for scientific research to validate the indigenous plant use categories in different use criteria. Biodiversity-based development holds promise for contributing to sustainable utilization of EIWPS and related industries or traditions. Therefore, the endeavour to sustain or revive EIWPS in the mountain ecosystems will reduce the imbalances resulting from encroachment of urbanization over the traditional way of life. The success of such an endeavour depends on the compatibility and complementarity of indigenous and scientific knowledge.

As non-domesticated species of wild flora, the development of plant resources needs to be dealt with beyond the local niches. Creation of agricultural production for EIWPS in the mountain ecosystems will satisfy biodiversity-based socioeconomic demands. Also establishment of oriented research plans aiming to evaluate of plant germplasm and genetic improvement, food and non-food uses, economics of domestication, and ecology and agronomy will unravel the socioeconomic and environmental side and support conservation and sustainable use.

In conclusion, the success of sustainable plant use in the forests of arid regions and their conservation, as based on indigenous and scientific knowledge, need to be firmly grounded in socio-cultural realities, plant species abundance, and rate of exploitation. Further studies are underway to carry out thorough analysis of indigenous local knowledge of plant resource use and conservation, looking at gender and age, from the young to the old.

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